802.11 and Bluetooth Coexistence Techniques

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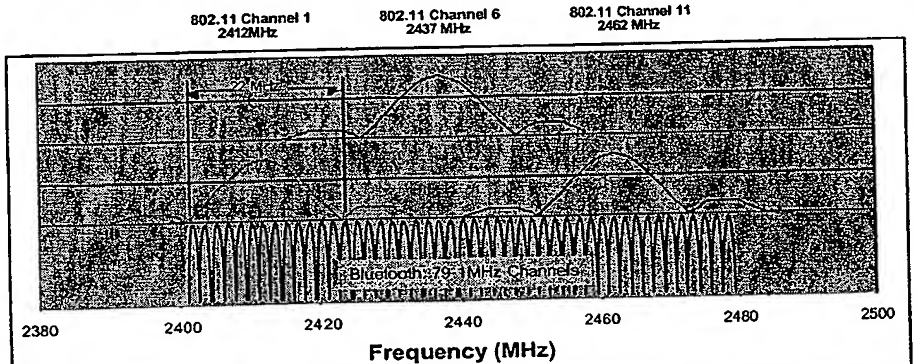
Agenda

- The coexistence problem
- Applications for simultaneous operation of Bluetooth and 802.11
- The 802.15.2 recommended practice
- The Blue802 coexistence solution
- Similarities and differences between the approaches.

Basics of 802.11 and Bluetooth

- 802.11b and Bluetooth occupy the same 2.4GHz band
- 802.11b uses DSSS modulation, 20MHz width
- Bluetooth uses FH modulation, hopping over the entire band, occupying 1MHz at at time. Hopping rate is 625uS.



The interference problem

- Bluetooth operation interferes with 802.11b
  - Long 802.11b data packets at lower data rates are more vulnerable to collisions with Bluetooth.
  - Problem is severe as antennas get within 1 meter of each other. It is a localized effect.
  - At long distances to Access Point, 802.11b throughput <1Mbps with possible disconnects.
  - The problem is exacerbated by the usual 802.11b rate fallback algorithm.
- 802.11b operation interferes with Bluetooth
  - High power 802.11b can saturate Bluetooth receiver.
    - Regardless of whether the Bluetooth hop is in the 802.11 band.
  - 802.11b can cause increased Bluetooth errors in the overlapping band.
  - Prevents simultaneous operation of both in a notebook PC.
  - Reduces Bluetooth throughput and interrupts SCO (Synchronous Connection Oriented) links.

Classes of coexistence

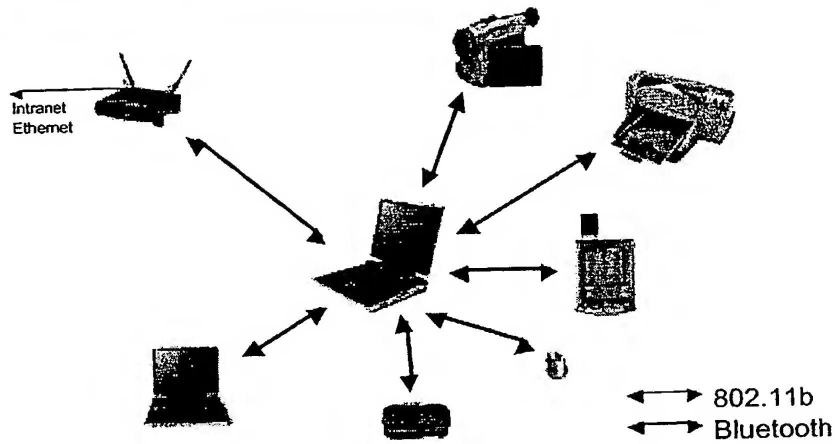
- Collaborative with co-location
  - Bluetooth and 802.11 in the same notebook computer or PDA, with some inter-radio communication mechanism.
  - Potentially using shared antennas
- Non-collaborative without co-location
  - Notebook with 802.11, cell phone with Bluetooth

	Co-located	Separated
Collaborative	MAC layer coordination, time sharing	Infeasible due to separation
Independent	Ineffective due to shared antenna and RF de-sense	Adaptive Frequency Hopping, Power control.

Adaptive Frequency Hopping

- Implemented in the Bluetooth radio
  - Certain frequencies in the are identified as "bad" and removed from the hopping sequence.
  - The use of reduced sets of frequencies for FH radios was approved by the FCC in 1999
  - AFH is in the process of standardization by the Bluetooth SIG. It will be a part of Bluetooth 1.2, due in late 2003
- Very effective when Bluetooth is not co-located with 802.11.
  - Greater than 1 meter of separation.
- AFH loses effectiveness if all of the 2.4GHz band is filled with 802.11 signals or interference.

Application Scenarios



Dual Mode Client Application Scenarios

- If only one wireless connection is available, coexistence is not an issue – the unused radio is shut down.
- When does simultaneous operation of Bluetooth and 802.11 make sense?
  - Internet access with 802.11, printing to Bluetooth
  - Downloading email from a server with 802.11, synchronizing to a PDA with Bluetooth
  - Totally wireless desktop – WiFi for network access, Bluetooth mouse and keyboard.
- What doesn't make sense?
  - Internet Access via Bluetooth
    - Although Bluetooth Access Points are sold for this purpose, you wouldn't use Bluetooth for Internet if 802.11 was available.
  - File Transfer via Bluetooth
    - Again, if you have 802.11 available, why use Bluetooth?

Bandwidth and latency requirements

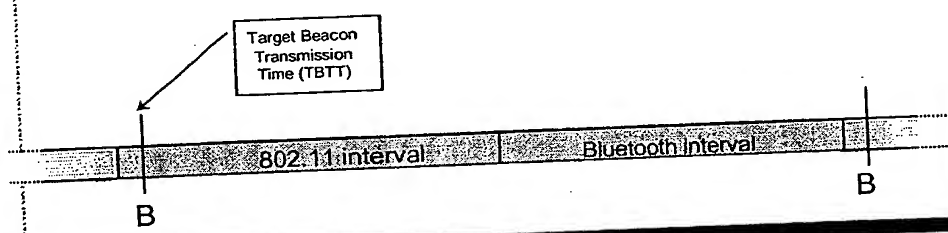
- In the application scenarios where both 802.11 and Bluetooth are active simultaneously:
  - 802.11 traffic is often bursty – EG accessing web pages
  - Bluetooth bulk data transfer is sporadic – EG PDA sync and printing
  - Bluetooth has low bandwidth and low latency requirements – EG Mouse and Keyboard
- These requirements make time division multiplexing an effective coexistence solution

Issues with simultaneous operation

- Factors affecting RF De-Sense
  - Co-location (possibly on same card)
  - Antennas in close proximity, or shared.
- Quasi-simultaneous operation
  - Simulated by time division multiplexing between the radios rapidly.
  - Switching at the driver level is too slow
  - MAC to MAC coordination is required.
- 802.15.2 coexistence mechanisms
  - Time Sharing
  - Adaptive Frequency Hopping

802.15.2 - Alternating Wireless Medium Access

- Alternating Wireless Medium Access (AWMA)
  - Divides time into a Bluetooth Interval and an 802.11 interval.
  - AWMA is based on 802.11 Beacon Interval
    - Beacons are transmitted by 802.11 access points (AP) on a regular basis (typically every 100mS)

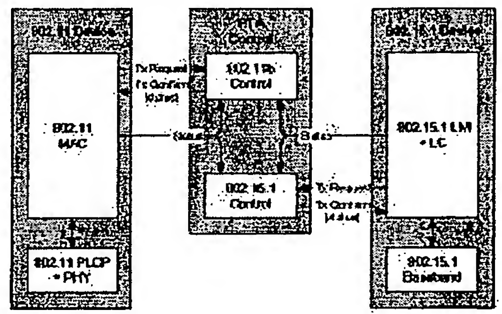


Limitations of the AWMA approach

- 802.11 APs must be updated to support AWMA
  - A new beacon element is required to convey the division of time.
- 802.11 Clients require mod to support AWMA
  - Clients must understand that AWMA is in use, interpret the time division, and inhibit transmissions during the Bluetooth time interval.
- The time division is global to entire 802.11 BSS
  - 802.11 / BT interference is LOCALIZED to specific stations.
    - AWMA is overkill unless Bluetooth is in wide, simultaneous use.

802.15.2 – Packet Traffic Arbitration (PTA)

- Packet Traffic Arbitration is the second coexistence mechanism described in 802.15.2
  - PTA uses a “control entity” with the ability to control both the 802.11 and Bluetooth MACs.
  - The control entity implements a handshake with both MACs to authorize transmissions
- PTA is time division traffic cop



Limitations of the PTA Approach

- The control entity requires detailed information on the state of both MACs
  - Most practical when both MACs are implemented in a single chip
- PTA may not be the ideal choice
  - 802.11 and Bluetooth systems may be implemented in separate modules
  - Customers want to integrate “best of class” chipsets from different 802.11 and Bluetooth vendors
    - PTA limits customer choice

Overview of the Blue802 approach

- Blue802 is a novel coexistence mechanism
  - Combines best aspects of the 802.15.2 collaborative coexistence mechanisms.
- Blue802 uses 802.11 Power Save mechanism
  - 802.11 Power Save defines a "sleep state" for the client station.
    - Client notifies AP that it is entering Power Save
    - AP queues traffic addressed to that station.
    - Client "wakes" periodically for AP Beacon
    - AP Beacon informs client if any traffic is queued.
  - The ability to cause the AP to hold downlink traffic allows the station to grant time for Bluetooth operation.

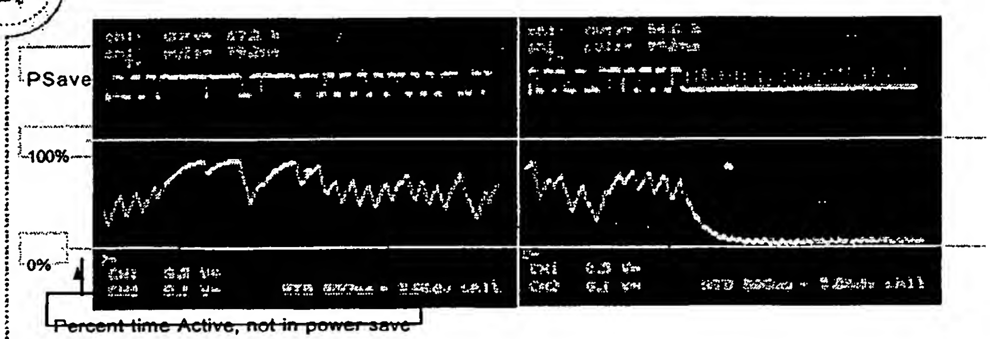
Blue802 highlights

- Blue802 is a collaborative coexistence mechanism that operates at the client
  - An 802.11 station is co-located with a Bluetooth radio.
- The Blue802 coexistence operates in the vicinity of the client. Other devices in the area are not affected.
- Blue802 does not require any changes to the 802.11 standard, and it works with existing Access Points.
- Blue802 protects Bluetooth HID peripherals
  - Low latency HID messages are not delayed.
  - Bluetooth Mouse and Keyboard operation is unaffected by concurrent 802.11 traffic.
    - Mouse action is smooth and fluid.

Dynamic sharing

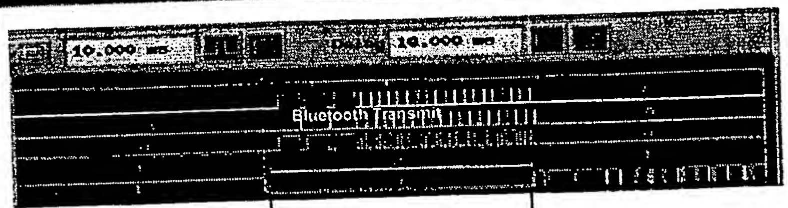
- Blue802 dynamically shares bandwidth
  - Allocation is based on instantaneous 802.11 and Bluetooth traffic
  - 802.11 is a shared medium
    - Many stations can be associated to an AP
    - Any single station gets a portion of the available bandwidth of an AP.
  - Since the 802.11 radio is not fully used, the unused time is given to Bluetooth
    - A side benefit is the savings in power.
  - Even if 802.11 is heavily utilized, Bluetooth HID devices are still protected.
- AWMA can only provide a fixed time alternation.

802.11 Dynamic Power Save Operation



- "Psave" signal is active high, idle low. Bluetooth operates in idle low
- 802.11b is mostly idle during typical web browsing
- Bluetooth gets near full throughput

Detail of Power Save Interval



.11B Power Save Idle

- During the period where 802.11 is in power save mode (here about 35mS), Bluetooth conducts its master / slave frame exchanges using 625uS slots.

Bandwidth On Demand

- Normally, Bluetooth defers to 802.11.
  - Bluetooth is inhibited until 802.11 enters power save.
- Bluetooth "priority" events must always be serviced
  - These events (e.g. from HID devices) can use an override mechanism to temporarily disable 802.11.
  - An 802.11 packet can be lost in this case, but the normal retry mechanism compensates.
- If the 802.11 radio is very busy and never enters power save mode, Bluetooth throughput will be very low
  - Bandwidth On Demand can increase the amount of time given to Bluetooth (at the expense of 802.11 throughput)
- Bandwidth on Demand supports the (relatively rare) case where bulk data transfers are taking place on both 802.11 and Bluetooth.

Conclusion

- Bluetooth & 802.11 coexistence is an issue
    - Localized effect
    - Must be dealt with when BT & 802.11 are on same machine
- 802.15.2
    - Defines several coexistence mechanisms
        - May require changes to the 802.11 standard and existing devices
        - Limits implementation options & vendor choice
        - Non-collaborative mechanisms such as AFH are widely accepted
- Blue802
    - Works with existing 802.11 standard
        - Operates locally at the client
        - Protects 802.11 traffic when Bluetooth is in operation
        - Provides seamless simultaneous operation
        - Protects Bluetooth HID traffic even when 802.11 is heavily used